ILRI
INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

Farming in Tsetse Controlled Areas

FITCA

FARMING IN TSETSE CONTROLLED AREAS
FITCA

Environmental Monitoring and Management Component

E M M C

Project Number : 7.ACP.RP.R. 578

Land-use/ land-cover Mapping

GPS Methodology

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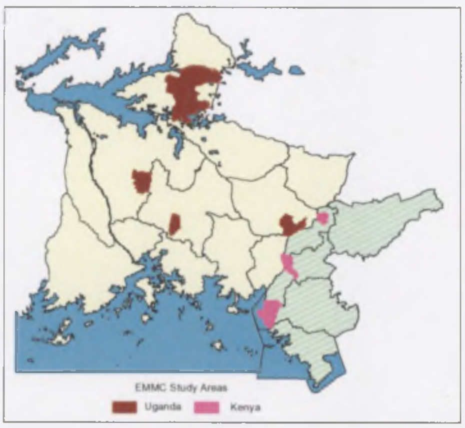

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1 OVERVIEW: FITCA Project

The regional project FITCA (Farming in Tsetse Controlled Areas) has a general objective to integrate tsetse control activities into the farming practices of rural communities such that the problem of trypanosomosis can be contained to the levels that are not harmful to both human and the livestock and environmentally gentle and integrated into the dynamics of rural development and are progressively handled by the farmers themselves. The project is hosted by the Inter-African Bureau for Animal Resources of the African Union (AU-IBAR) and covers areas with small scale farming in Uganda, Kenya, Tanzania and Ethiopia.

EMMC (Environmental Monitoring and Management Component) is the environmental component of FITCA. It is implemented by ILRI in collaboration with CIRAD (as member of SEMG, Scientific Environmental Monitoring Group). This regional component has been charged with the responsibility of identifying of monitoring indicators and methodologies, as well as the development of an environmental awareness among the stakeholders. It contributes to propositions of good practices and activities mitigating the impacts and rehabilitating the threatened resources likely to result directly or indirectly of tsetse control and rural development.

The FITCA EMMC project was written by Dr. Robin Reid of the International Livestock Research Institute (ILRI) a future Harvest Centre supported by CGIAR (Consultative Group for International Agricultural Research).

The present report has been prepared under the responsibility of the leading group of EMMC:

- Dr Bernard Toutain, agronomist, coordinator
- Dr Joseph Maitima, ecologist

2 Introduction

The objective of Environmental Monitoring and Management Component (EMMC) is to develop an information system and methods for monitoring the direct and indirect effect of farming in tsetse controlled areas (FITCA). One way of monitoring is through surveying and mapping using available methods for change detection especially on land use land cover over time. Maps can be created or derived using either ground survey or remote sensing methods.

The main objective in this ground GPS mapping is to capture the area and the distribution of various land use land cover at farm level. This will lead to deriving the required baseline indicators of land use change for the monitoring and management purpose. The information will also be used in training and classification of high-resolution satellite images for mapping the wider EMMC and FITCA study areas.
Ground survey techniques are time consuming and laborious but one is able to capture all possible land phenomena's from the social economic using questionnaires, land ownership using cadastre survey to land use land cover at farm level using GPS ground mapping.

Remote sensing techniques are quite fast and efficient in deriving maps of phenomena's, which can be observed via satellite depending on the images spatial resolution (scale). The image scale is no longer a major issue since there are new satellites, which are able to map even at a scale of one meter or less e.g. SPOT (2.5 KM), IKONOS (1 M) and QUICK Bird (66 CM). The main problem with these high-resolution products is their unavailability and high cost. They are acquired on request unlike the low-resolution images of LANDSAT (30 Meters), which is acquired after every 15 days for most parts of earth surface.

To achieve the environmental monitoring objectives three types of survey have been done namely land use and land cover mapping using GPS at farm level, Vegetation composition survey and household survey using questionnaires and recording the position of the homesteads using GPS.

GPS mapping methodology follows various steps and processes, which can be summarised as; Preparation in terms of logistics and tools required, staff recruitment for fieldwork, field training, fieldwork organisation, data collection and storage (tracking and downloads), data editing and treatment in the field and after the field, data analysis, generating statistics and map production. This report describes in details these practical steps.

3 Preparations and logistics

3.1 Contact person and Study sites

The EMMC study sites had been identified for detailed land use / cover survey and mapping within the areas covered by FITCA project. Identification was by assessing ecological sensitivity of sites based on potential impacts likely to occur as a result of tsetse control (EMMC Annual Report 2002. The sites are within villages covering areas between 4 and 5 Km2. Five sites were identified in Uganda and three in Kenya. In each of this sites contact persons were identified to assist in arranging for field work and other required logistics. The contact people are mainly the district FITCA project leaders who are based in the district headquarters. National contact person was also identified through whom information to the district contact person is relayed.

3.2 Sensitisation

Preparation for fieldwork involves a lot of communication and arrangement between the contact persons and the office. The contact persons have to be informed of the exact dates of operation and site location at least one month before. This gives them ample time to inform the administrative hierarchy from national to the village level. Ground mapping involves direct interaction with the local community who are the owners of land resources being mapped. People at the village level where actual work will be done needs to be sensitized on the work to be done so as to clear any mis-understating that might arise. Land is a very sensitive asset to the farmers. A major mis-conception by farmers during field mapping is that people are surveying their land for some ulterior motives. Such issues should be clearly explained to farmers before hand for smooth running of the fieldwork. Most of this sensitisation is arranged and done through the contact person. Part of the explanation is also done during the fieldwork through local villagers who are hired as field guides.

3.3 Recruitment

The fieldwork is normally headed by the project supervisor who is also the project ecologist mainly involved in the vegetation survey exercise. A GIS analyst who co-ordinates all the work dealing with land use mapping and manages all the data collected in the field assists the ecologist.

The contact person arranges and recruits the required local field assistants for GPS mapping, vegetation survey assistant and the field guides.

The general requirements for GPS mapping assistant is education level of at least form IV who is able to communicate in English and the local language. The person should also be physically fit since the work involves a lot of walking for long hours and in difficulty terrain. Mostly we have preferred young school leavers waiting to continue with their education or looking for a job. This group is eager to learn and they are satisfied with the per diem provided. A field guide assistant should be somebody well known in the village (an elder) that is able to communicate to the people information about the exercise and also knows the village geography so as to guide the others involved in the work. Recruitment is open to both women and men. Normally six people are required for GPS mapping, one person to assist in vegetation survey. Three field guide assistants are required to assist the three survey groups as mentioned above. The guide assisting the household group also acts as an interpreter.

In vegetation survey a field botanist is recruited to assist the ecologist in identifying and classifying the plants. A botanist was identified and recruited in each country. The same botanist was used in every site within each country.

A sociologist is required to administer the questionnaire for the household survey. This person was identified and recruited to assist for all the sites within each country.

3.4 Accommodation

Accommodation should be arranged for none local staff within the nearest town to the study sites. This should be secure and have electricity for operating the electronic tools required for fieldwork e.g. computers. The rooms should offer a conducive working environment.

4 Tools and Budget Needed

4.1 Transport

Transportation is a very important factor in this work. Two four-wheel drive cars are required. They are used to transport people from the hotel to the site and also within the site. One car is normally used by the household survey group to move from home to home. The other car is shared between the GPS mapping group and the vegetation survey group. The leader of GPS mapping is at times required to move and assist those who might be having problems with their GPS machines. One car has always been provided from Nairobi, which also transports the personnel and the required tools. The other car is hired locally where we have always preferred the local FITCA project vehicle.

4.2 GPS machines and accessories

The main tool used for this mapping activity is a hand held Global Positioning System machine (GPS). The available make used are GARMIN systems both model CX and XL. The CX model has a storage memory double that of XL and stores 1000 waypoints and 2056 track points. It is advantageous to use the CX model due to the superior memory capacity. One is assured of working for the whole day without requiring data download to a computer to release the memory. This is important because downloading at the site is cumbersome and time wasting. It is much better to do it at the end of the day.

Hand help GPS run on 4 normal AA size batteries. In this work a set of 4 would run a machine for two days. Depending on the number of machines and the number of days enough high quality batteries should be purchased to last the whole fieldwork duration.

The accuracy of a GPS depends on how good it is receiving signals from the satellites. If the GPS will be used inside a car then it is necessary to have an antenna for better reception. When working in the open field an antenna is not required. But is good to have one just incase you might need to track something like a road while being inside a car.

A data download cable is a must for GPS land use mapping. As explained above the memory of a GPS is small and data must be down loaded to a computer at least once in a day. It is important to make sure you test the compatibility of the cable and the GPS machines that are available and the computer to be used before going into the field. It is also advisable to have at least two cables just in case one gets spoiled.

4.3 Computer and accessories

Computer hardware and software are required for this mapping work. A laptop machine is the most ideal and convenient. It should have the required devices such as external drives for backups. The machine should also have compatible ports (serial, parallel, UHB) for connectivity of peripheral devices. The devices to be considered in this particular work are the GPS and the download cables printers and also Digital camera if available.

Software tools are as important as the hardware tools mentioned above. This being a mapping exercise a desktop GIS is required. This must be compatible with other software used for the ease of data transfer and management. Common desktop GIS software used is ArcView from ESRI for viewing the spatial data and producing maps, which can be inserted in documents or printed out as hard copies. The capability of producing maps is important in this exercise since they are used for reviewing the progress of mapping work and identifying any errors that might occur in the mapping process.

Another important software is a GPS data download interface into the computer. This software should allow one to save the downloaded information in a format that is compatible especially with the GIS systems. In this work, the software used is called OziExplorer. It is compatible with ArcView and can save download GPS data directly into shape files for ArcView manipulation.

Laptops normally run on electricity as well as on a battery. Most laptop batteries can last between 2 to 3 hours when they are fully charged. If one is not doing much downloads on the site then one battery would be enough else it would be advisable to have a spare battery for proper power backup.

A printer is also required for this type of fieldwork. It is mainly used for producing maps that assist in making a days working strategy and monitoring. There are small portable ink jet printers (different makes) that are very ideal for this work in the field. One should also not forget the ink cartridges and the required connecting cables.

It should be stated here that a computer plus the mentioned devices is a must since all the information collected in a day will have to be analysed for monitoring the work progress and must be backed up due to the storage limitation of a GPS.

4.4 Stationery

Stationeries required for this exercise include pens, pencils and rubbers, writing pads, clipboards and printing papers. Enough data recording sheets should be prepared before the fieldwork starts. The data sheets include; GPS recording forms, Vegetation recording forms and the social economic household survey questionnaires (see attachments).

4.5 Communication in the field

Communication among the surveying and mapping group members is very important. Where mobile phone systems are available they are the best means for communication. This is more so between the GPS mapping members who work in different and far apart areas. At times one might encounter very simple problems with the GPS machine and through the phones this might be sorted out very easily. Also if one needs to move and assist or be assisted in a major problem one is able to communicate with the driver to be picked in a specified position for transportation. Hence communication using mobile phones should be facilitated as an essential requirement in this mapping methodology.

4.6 Other tools

First aid Kit
Measuring tapes
Panga
Polythene papers for holding soil
Bucket for mixing soil samples
Poles and pole clothes for demarcating vegetation plots and quadrants

4.7 Budget

The budget depends on the number of days required for fieldwork and the distance to the study area. The table below gives an indication of the costs involved in 10 days mapping and surveying work.

Table 1: A sample budget for a 10 days fieldwork

Item Description	**Number**	**Unit cost Us $ (* 10 Days)**	**Total Cost US $**
Ecologist	1	1,100	1,100
Sociologist	1	1,100	1,100
Botanist	1	410	410
GIS Analyst	1	1,100	1,100
GPS Assistants	6	70	420
Field Guides	3	30	90
Drivers	2	550	1,100
Stationery		100	100
Transport		1,500	1,500
		Totals	**6,920**

5 Field work organization

The fieldwork schedule can be divided into the following phases; traveling, initial training, data collection and verification. It is important to verify that all the required tools as enumerated above are available and they are in working condition. A sufficient amount of stationery and other consumables should be availed as it is very difficulty to purchase them in the field.

5.1 Training

5.1.1 Introduction

After traveling to the study site the first two days are reserved for training the recruited staff on the application of GPS in mapping, familiarisation of the study area and the local community. The contact person should be able to organize for a room where training can be conducted for the two days.

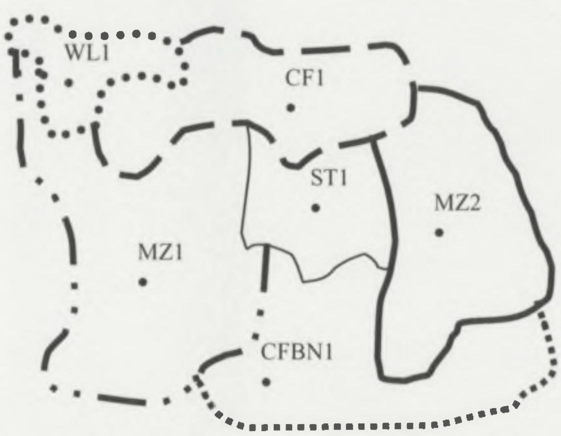
The main objective of GPS training is to enable the trainees to use the machine for recording waypoints and tracking of poly lines to define various land use land cover types at farm level and coding. It is not the intention of the course to go into the complicated concepts of GPS systems. By the end of the training the student should be able to manipulate and capture spatial data using the system.

To most trainees, it is usually their first time to see and use a GPS system. It is important to start from the simplest concept of operating the system such as switching on and off, replacing the batteries and scrolling between different menu systems of the GPS pages.

5.1.2 Map Concepts

The concepts of mapping should be introduced in the simplest terms possible. This should be explained in terms of a polygon which defines a land use boundary (Track) and a polygon label point, which describes the land use class or type (Waypoints) (Diagram 1). The trainees should understand the GIS concept of data storage where tracks that overlap do not need to be tracked (Digitized) twice. These saves time, GPS memory space and reduce the work required in data editing at later stages.

Diagram 1: GPS MAP CONCEPT



• CF1: Coded Label Point Representing a Coffee polygon

5.1.3 General GPS Manipulations and setups (GERMIN)

There are many different types of GPS systems in the market but the basic principle of GPS system operations is the same. In this particular work GERMIN GPS systems were used. It is important for the trainee to understand some of the basic observations and setup required before practical application of the system. This includes

- The buttons that are used to manipulate the GPS, which includes the switch for on and off, waypoint marker, Enter key and the scroll bar buttons. The battery pocket and how to replace batteries, the antenna and the data download ports should all be demonstrated to the trainees.

- Observing the estimated position error (EPE) on the GPS satellite page that measures the accuracy of the GPS recorded position depending on how well it is receiving the satellite signals. One should start using the system when the EPE is within the acceptable ranges, which in this case we had set it to 5 meters. This implies that the positional accuracy is within $\pm$ 5 meters of the true location. The setting of contrast for better visibility should be demonstrated. It is a common mistake to find the trainees complaining about the failure of the machine only to find that the contrast has accidentally been set to zero. The user should also be able to view the battery level meter so as to know when to replace the batteries.

- The navigation system should be set depending on the users requirement. This includes position coordinate system that could be degrees, UTM and many others. The map datum, Download interface and other relevant map parameters should be set accordingly.

- Knowing how to read the position co-ordinates is important. One should be able to differentiate the x and y coordinates especially when they have to be recorded on paper.

Example 1: GPS setups (GERMIN)

Setup Menu
  System
    Normal Operations
    Offset + 3.00 hrs
    Contrast
    Tone
Navigation
  Position format UTM/UPS
  Map Datum (arc 1960)
  Units (Metric)
  Heading (Auto)
  Interface GARM/GARM

Understanding system manipulation technique improves the speed of doing work and production of accurate map data.

5.1.4 Tracking, recording way points and coding

This is the main area of training because it is through this process that one is able to capture data required for land use land cover mapping on the ground. The process involves identifying the class type and the estimated boundary, walking around it with the GPS on and recording or tracking the path that defines the polygon, recording a waypoint in the middle of the tracked polygon and assigning it an identifying code (label point) using the agreed coding system.

Example 2: Track set up options

Record: {FILL | OFF}
Time interval: HH MM SS
00 00 05

Memory use: 20 %

5.1.4.1 Tracking

In a GERMIN GPS system the tracking setups and manipulations are performed within the map drawing page. The time interval for recording is set once depending on the average sizes of land use polygons to be mapped. This can vary between 5 and 10 seconds where the larger the polygons the higher the time interval should be set. Under the track set up option one is able to start or stop the track recording process by setting the recording option to ON or OFF respectively. One is also able to observe the amount of memory used and the amount remaining.

5.1.4.2 Waypoint

After tracking a polygon a waypoint needs to be recorded inside the polygon to identify the land use type. There are two ways of recording a waypoint inside the polygon; one can walk inside and record a way point somewhere within the polygon or you can use the PAN technique to scroll your map such that the position marker appears in the middle of the already tracked polygon. The PAN technique is important especially when there is no accessibility into the polygon e.g. when mapping a thick bush or a fenced and inaccessible compound. The PAN technique is also advantageous since it reduces the distance one has to walk by not having to walk in the middle and out again for tracking the next polygon. Whichever method is used a way point is recorded by marking inside the polygon.

5.1.4.3 Coding

The purpose of having a waypoint in a polygon is for identifying the type of land use within. A way point will be meaningless if it is not properly coded using an agreed system that make sense to the people concerned. In this method a coding system of all possible land use types has been developed which uses two letter codes (See Appendix A). Where there is a mixture the two main cover type codes are used starting with the dominant one then followed by the second code. As an example the following are codes used for various crops Maize-MZ, Coffee-CF, Bush--BS, Banana-BN, Woodland-WL, and Homesteads-ST. Hence a mixture of coffee and banana will be coded as CFBN. Since duplicates are not allowed when coding in a GPS, land use and cover types should be coded with a sequentially assigned number such as MZ1, MZ2, MZ3, CFBN1, and CFBN2 within a days session. The sequential coding can be repeated again after the data has been down loaded and deleted from the GPS. The coding system is limited to a maximum of six characters (alpha-numeric) as dictated by the GERMIN GPS waypoint name.

After assigning the correct code (name) to a waypoint it is finally saved and can be viewed on the GPS map page. The coding information saved in the GPS is also recorded manually on a pre-designed waypoint data form (See Appendix B) with the full description of the code for reference during data verification and editing at a later stage. The date, the number assigned to the GPS and the name of the user are also recorded on the data sheet.

This process (tracking, waypoint recording and coding) is repeated again and again for every polygon that is to be mapped. The trainees should be made to practice this process as many times as possible until they perfect it. Else without mastering it no proper work will be accomplished.

5.1.5 Field Practices

The training also involves field practical in the second day when the techniques learned in class are practiced and perfected. The process starting and stopping the tracking of a poly line, recording around corners by having a short pause to have

smooth corners and finally recording and coding the polygon label points are demonstrated and practiced in the field.
During practical training, the possible land use types are identified and clearly described and agreed upon by all so that classes are mapped and coded the same by everyone. Any new unique land use types are also identified and given new codes. The trainees are also allowed to come up with new codes when they encounter new cover types but it must be recorded quite clearly on the data sheets.

5.1.6 Common mistakes and errors

There are many common but very serious errors that are encountered and it is important to mention some of them here;

- Forgetting to Stop tracking at the end of a polygon

Many a times is when the trainees forget to stop the track recording which should be done by switching the track record to OFF mode at the end of a polygon. This results in recording many meaningless lines during the process of recording a waypoint. This also results in exhausting the storage memory within a very short time.

- Duplicating codes

As explained above a GPS does not allow duplicate codes, but at times trainees forget to record codes on their data sheets leading to them trying to use the same code again which is rejected by the system. The tendency is to think there is something wrong with the GPS. This issue of duplicate codes should be emphasised.

- Changing record interval by mistake

This happens and it can be very frustrating. If for example the set time is changed to one hour, this means that a single vertex of a track will be recorded after one hour. The logical conclusion is that the GPS is faulty and is not recording tracks. The other possibility is when it is changed to less optimal values, it will continue recording but the polygons have very unnatural shapes with straight lines and sharp corners. Hence it is advisable to check the time interval set up when such problems are observed.

As explained in the training objective the aim is to enable the trainees assist in capturing land use and cover data for the purpose of mapping and deriving the relevant statistics. The training should achieve this objective, which can be verified by checking the type of outputs from the trainees. Usually they improve everyday and they are perfect toward the end of the fieldwork.

5.2 Data capturing and organisation

After the first two days of training most trainees are ready to start working on their own. The strategy when organizing the group for data capture is to make sure that there will be no overlap and also no possibility of omission within the identified study area. The demarcation of areas to map should be based on tracks, paths, roads and other physical features such as swamps and rivers existing within the study area. Such features should be identified and mapped where possible through the assistance of one of the recruited field guides. The mapping group leader should do this during the first day of working after the training. The exercise also assists the leader to familiarise with the study area and be able to organize, assign and monitor the mapping work.
Each GPS mapping group member should be assigned a separate area to map on the ground to reduce the possibility of overlap or omissions. Mapping leader should

always be accompanied by one of the locally recruited field guides to act as the interpreter. This is important because although the locals are usually informed about the exercise before, one will always need to explain to the people you meet on the ground. The locally recruited staffs can move on their own since most likely they can communicate using the local or any other common language in the site.

5.2.1 Timing and communication

During the daily data collection exercise, it is necessary to arrange on how to contact each other incase of any problems. Communication through mobile phones is the best means where network is available. Else it is in order to arrange a central meeting point daily which should be located a long the roads or tracks. The driver should facilitate the communication by being within reach from the agreed central point. On contact by one of the personnel, they can then look for the leader whose working location should be known by the driver.

The working hours are from 8am to 4 Pm without lunch break. This also includes travel time to and from the hotel. Through experience we realized that too much time is wasted in picking up and dropping back the workers when a common lunch is arranged. The practical way is for the workers to carry their own packed lunch and water which they can eat at their own convenient time.

5.2.2 Monitoring

Work monitoring and review by the leader is an integral part of the field organization and data capture. The leader takes part in the actual GPS mapping work but should also spend time to visit areas mapped by others. These visits are used to assess the quality of work being done and take any field notes required for data editing and analysis at a later stage. Maps are important products to use in the monitoring exercise. They should be prepared and printed at the end of the day and be ready before the start of the next days work. Mapping leader should be ready to work extra hours in the evening to download the data and prepare the maps. The maps should consist of the tracked polygons with the marked waypoint (polygon label and the corresponding assigned code or name used to identify land use type.

The maps assist in making the days working strategy in terms of work assignment and identifying the common errors and rectifying them. The responsible person through the guidance of the mapping leader should do the error correction. Maps also assist in identifying sample areas to visit and confirm the type of classifications recorded. Field notes are also made on the maps for reference during data editing and correction.

5.2.3 Field Errors

Some of the common and most important errors and how they are made are as shown and described below;

- Missing label point

This happens quite often when one forgets to record a waypoint after the tracking of a polygon. It can also happen if one forgets to save the waypoint in the GPS after assigning the code.

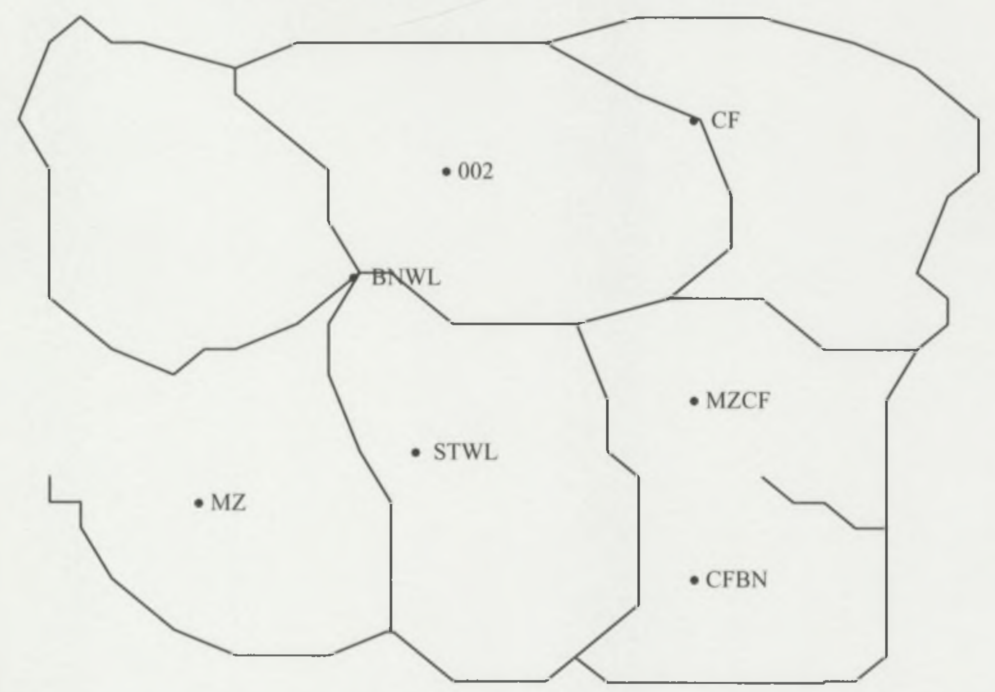
- Misplaced label point

This happens when one forgets to walk or pan to the center of the polygon. Normally such misplaced labels will appear along the boundary in which case it is difficulty to know where they belong.

- A none coded label

By default if a waypoint point is not assigned a code by the user, the system automatically assigns a code in form of a sequential number (e.g. 001, 002, 003....) to the waypoint. Again this should be pointed out and should be rectified by the user.

1.1.1.1.1 Diagram 2: GPS Mapping Errors



- More than one label

At times you find polygons with more than one label point and codes. This should be rectified by ascertaining the correct label code

- Unclosed Polygons

These are polygons that are either not closed or the boundaries are not complete.

- Undefined Label codes

This is usually caused by typo error when assigning the codes.

At times one might find unusually big polygons, which must be confirmed. This happens when there are extensive land use types like maize fields or woodlands and it is important to check within such polygons since there is high possibility of lamping together other smaller land use that might be found inside.

In general it is very important to walk around the study area and confirm most if not all of the classified land uses and covers on maps and make necessary notes. The importance of having a portable printer for map production cannot be overemphasized. Without a printer one has to organize on how to print the maps elsewhere which might be very difficulty and time wasting in the mornings.

5.2.3.1 Data Download, Organisation and X, Y Shift.

Data downloads from GPS to computer hard disk should be done at the end of the days work or on the site as soon as a GPS tracking memory is full. As explained earlier, the available software for download is called OziExplorer. The GPS and the computer software interfaces must be set for proper communication (See GPS and software manuals). A functional download cable is also required. It is only after verifying that data from GPS is properly saved that one can clear the GPS.

Example 3: Interface Setup

2 OZI Setup

System
- The GPS make (Garmin) 12XL or 12CX
- Set up the Map datum
- Set up the data and map paths

Maps
- Country region (North & East SE)

GPS
- Make Garmin 12xl Symbols
- Garmin Symbols

COM
- Com Port (1,2,3, 4 or (5 UHB) port))
- Parity none
- Upload/download baudrate 9600
- NMEA baudrate 4800

3

4 GPS Setup
- Type: GARMIN/GARMIN and
- Interface: HOST

Downloaded data must be organized in such a manner that it is easily identified and related to the person (GPS) that mapped it. There are two related data set that are collected from the field using a GPS namely the tracks and the waypoints. Downloaded data is saved in the original OZI format and also in GIS ArcView format for map production and data verification. Data should be saved in different directories to differentiate the waypoints from the tracks and between OZI data format and ArcView format. The file naming convention should be such that one is able to identify the GPS (user) used, the date, and the number of downloads in a given day. An example of file naming convention is tr-gp2-d22-1 implies that this file consist of tracks (tr) from GPS number two (-gp2) of data collected on date 22 (-d22) and was the first download (-1) of the day. The corresponding waypoint file should then be named wp-gp2-d22-1 carrying the same meaning as for the tracks. This kind of data organization makes data management very easy and eases the work of monitoring and advising each of the workers and data editing at later stages. Similar data organization is used for the household and vegetation survey GPS data sets. It is good practice to make backup of downloaded on daily basis just in case there is failure or loss of the computer being used.

One shortcoming in using OZI explorer software for data download is a constant shift that occur on feature locations both in X and Y directions. The shift should be calculated and recorded into an excel file for use at a later stage in transforming the data into the correct positions. This can be done by recording the x and y position of a few selected waypoints before download from GPS and after download into ArcView and calculating the averages (see transforming section example 4 below).

5.2.4 Finalizing Fieldwork

One major objective before the end of fieldwork is to have a complete and continuous map sample of the study area. The final map product should not contain unmapped areas within the selected study site. This can be achieved through proper work assignment as guided by the results of daily monitoring of work progress in relation to the estimated total area of study site. The last day or two should be used for verifying the work done by the mapping group and completing unmapped parts of the study site. Verification maps needs to be printed out showing the coding of all the polygons to identify errors and taking necessary notes for data correction. At the end of the exercise it is important to make sure that all the recruited staff have been paid and have handed in all the data record sheets, which are also used as reference materials for data editing.

6 Data editing and formatting

Data collected from the field has got many errors, which need to be corrected before being used for map production, statistical analysis and spatial analysis. The errors are both spatial in nature (related to the position of tracks and label points) and attribute errors dealing with the coding or classification of land use and land cover types. The systems used for data editing and correction should be able to handle both the spatial and attribute data sets. Some of the software systems used for editing include the GIS related ones such as ArcView and ArcGis and also Microsoft Access and excel for data formatting. The field data is transferred from the field laptop to the workstations for the next steps of data editing and processing.

6.1 Editing in ArcView

Data is edited per file based on the filing system explained above. Editing per file makes it easier to use the field data sheets and field notes which are also on the basis of the users and the date of mapping. Both track and waypoint information is edited concurrently. Editing using desktop GIS is easier due to the flexibility of window-based tools in which map features can be moved at ease.

The main editing and correction of the data can be done quite easily within ArcView environment. Using the vertex editing tools the polygon tracks are moved to make properly closed polygons. The tool is also used to remove duplicate lines where there is overlap especially along the boundaries between different days work and between boundaries of different GPS users.

The attribute data is edited and corrected using the tables editing tools where labels are assigned consistent codes. This type of harmonization is important since different codes apart from the agreed ones might have been used for a particular land use type. The accuracy of mapping and statistical analysis depends on properly harmonized and properly coded land use labels. The software also allows one to add new label points where they are missing and assign the relevant codes as shown in the field notes or the data sheets. One can also delete duplicate labels or move misplaced labels inside the correct polygon. The editing should be done such that every polygon appears to be properly closed and contains a valid coded label point. This should be applied to all the tracks and waypoints captured during the fieldwork.

After editing the single tracks and waypoint files they should be merged to form two single files one for all the tracks and the other for all the waypoints representing the whole study site.

6.2 Transforming

The data collected and downloaded using OZI explorer has a constant shift as explained earlier. It is important to transform the data sets by shifting it back into the right position as recorded by the GPS. ArcView has a projection utility to transform the data. The transformation is achieved by adding the calculated average shifts to the two parameters of false easting and false northing in the output file of the projection process (Example: 4) and refer to ArcView Manual). Any other data sets captured using GPS namely household and vegetation should be transformed as well.

Example 4: Data shift and transformation parameters Calculations (Iganga Uganda)

Calculated Average shifts

Sample way points	X Before Download	Y Before Download	X After Download	Y After Download	X shift	Y shift
1	547,619.00	74,404.00	547,700.51	74,096.84	-81.51	307.16
2	548,395.00	68,377.00	548,476.59	68,071.18	-81.59	305.82
3	548,270.00	71,853.00	548,351.69	71,547.12	-81.69	305.88
4	547,236.00	70,895.00	547,316.91	70.588.80	-80.91	306.20
			Average Shift		**-81.42**	**306.27**

Calculated output transformation parameters

	False Easting	False Northing
Input	500000	0
Shifts	**-81.425**	**306.265**
Output	499,918.58	306.27

6.3 Cleaning the codes

During data capture it was explained that codes are assigned an extra sequential number to overcome the problem of none duplicate codes in a GPS. The extra number should be removed from all codes for proper data analysis. The merged waypoints data base file can be edited using EXCEL package to replace all the sequential numbers.

6.4 Editing in ArcGis

In order to perform spatial analysis map data must have what we call topological relationship inbuilt into the data set. This is a mathematical relationship that organises and relates features that make up a map. The features include vertices, nodes, labels, arcs and polygons. The topological relationship allows spatial analysis to be performed, which actually differentiates map data from any other graphics. The final spatial editing of data is performed within the ArcGis environment, which has the capacity of building topology and identifying topological errors, which are not directly visible within ArcView environment.

The ArcView shape file data sets must be converted to ArcGis coverage format for processing. ArcGis provides conversion programs between it and other GIS software.

Arctools, a window based user interface within ArcGis environment provides the required utilities for data conversion, data editing and management (spatial and attribute), topological building and data display.

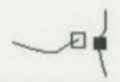
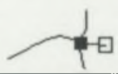
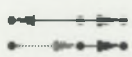
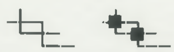
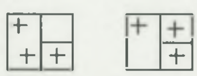
The initial process is to construct topology for the data sets. Two important commands used to construct topology are CLEAN and BUILD, where CLEAN uses a fuzzy tolerance when processing coverage to detect and create intersections while BUILD creates topology without adjusting the feature co-ordinates (See ArcGIS

Manuals). All possible errors are corrected using the available tools to create clean polygon coverage.

The two data sets (polygon tracks and waypoint labels) are finally joined to create complete land use coverage. Topology is again reconstructed for the combined coverage after which all-possible label errors are identified and corrected. The possible label errors include unclosed polygons, small sliver polygons, double label points, missing labels and many others (Example 5) which should be corrected with reference to the field notes and the GPS data records.

The topologically clean land use coverage is re-converted to ArcView shape file for mapping and further GIS analysis. The coverage also consists of automatically calculated fields of areas and perimeters of each mapped land use polygon for further statistical analysis.

Example 5: Common Editing Errors

Description	Error	Commands
	Undershoots	DRAWENV NODE DANGLE EXTEND arcs, or MOVE nodes, or CLEAN
	Overshoots	DRAWENV NODE DANGLE SELECT DANGLE, DELETE, or CLEAN
	Wrong orientation of arc or route	DRAWENV ARC ARROW FLIP
	Intersection errors	DRAWENV ARC INTERSECT MOVE 0 0, or CLEAN
	Coincident arcs	DRAWENV ARC INTERSECT SELECT DELETE
	Multiple or missing label points in polygons	SELECT $LABELS ne 1 DELETE or MOVE, or CLEAN or BUILD
	Unclosed regions	SELECT UNCLOSED APPEND ARC or ADD arcs

7 Data Analysis and Presentation

Data analysis is performed within various software environments depending on the type of analysis to be performed. The starting point of analysis is re-coding the land use data set into a clearly understood classification and description. This includes adding fields and assigning the full description of codes used, classification into generalised classes of land use and cover types in ArcView.

Summary statistics on area cover are generated based on detailed as well as the generalised classification. The statistics include counts, totals, averages, minimum and maximum area cover of each class type. This information is represented inform of graphs and tables generated in MS EXCEL. Land use distribution is presented inform of GIS maps generated within the ArcView environment (Refer to results of various sites).

8 Discussion

8.1.1 Application of the data

The data generated from this mapping exercise is mainly for monitoring the environmental changes that might occur due to activities of FITCA project. The information collected at these initial stages of monitoring will act as the baseline for reference with any future data that will be collected. Several parameters of change detection will be derived from this data. Some of these parameters include; the ratios of cultivated land to the natural land, the ratios and distribution of various categories of crops such as perennial, annual, cash crops, fodder and the extent of natural areas such as wetlands and the bushes. When this type of information is gathered and monitored within a time series it will give an indication of changes either positive or negative due to measure that have been taken within FITCA project.

The other method of monitoring changes is through the analysis of remotely sensed data acquired through high-resolution satellite images. To analyse this type of data, detailed ground survey data to train the satellite images for classification and production of land use maps for the greater FITCA project area is required. Again the GPS map data will be quite useful for the remote sensing exercise.

8.1.2 Seasonal timing

The GPS mapping exercise is a rigorous and time-consuming exercise. The judgement on classification of land use and identification of boundaries requires proper visibility. We have mapped some of the EMMC sites during different months and seasons of the year. Our experience has shown that it is best to undertake the exercise when the height of the dominant crops (e.g. maize) is less than a meter. This is mainly when farmers are doing the first or the second weeding. In such situation one is able to see far and wide enough reducing the possibility of missing smaller types of land use hidden within the more extensive ones. Also the identification of crops is quite clear and easy. During other seasons the following problems are likely to be encountered;

Before planting and during land preparation

> During this season, it is very difficult to classify crops. One can only guess the possible crop type to be planted from the remnants of the previous years crops. There is also a possibility of misclassifying land for cultivation with fallow or grazing land unless it is already ploughed.

Just Before and during harvesting

At this season the main problem has to do with visibility. The probability of missing some land use types is high due to the poor visibility. Again cropland misclassification is possible especially where crops have been harvested.

It is then very important to have a calendar of farming activities in a given study site to assist in deciding the optimal time to do the GPS ground mapping.

8.1.3 Definition of land use and cover classes

A clear and a precise definition of cover classes are important in any type of mapping exercise. Many classes overlap and they are usually very difficult to differentiate and classify. This is more so with the semi natural classes such as fallow, fallow grazing, grazing, bush grazing, and bush. The following is the definition of classes that were used in this mapping exercise.

Homesteads

These are areas within and around dwelling places consisting of houses, toilets, livestock sheds, crops, woodlot, fruits and other use types. The area is at least within ten to twenty meters around the houses and other structures.

Cropland

Areas used for cultivation of different crops, which can be re-classed into; cash crops, annuals, perennials, vegetables, cereals and fruits

Fallow

This are areas that have not been cultivated at least for the last one-year. They consist of young thickets and grasses. Old fallows may be more than three (3) years old with less grazing hence growing to become bushes. They are also used for grazing.

Grazing

These are mostly old fallows dominated by grasses and utilized for grazing with very few bushes or thickets.

Bush

These are old fallows consisting of specific bush plants such as (*lantana camara*) and other herbaceous plants. Pure bushes are very thick and most likely are inaccessible to livestock for grazing. An in between class of bush grazing consists of bushes with patches of grasses where livestock can graze.

Woodlots

These are scattered Pockets of planted or naturally growing trees found within the cultivated and settled areas. Most homesteads will also have woodlots that are used for wind breaking and providing shade and firewood.

Woodlands

These are extensive areas with between 20-80 % tree cover and a mixture of grasses, bushes and shrubs. Forest would be defined as closed woodlands (with over 80 % tree cover).

Swamps

An area where there is a mixture of water and plant species, mostly not easily accessible due to waterlogged and muddy in general. They have specific plant species as defined by botanists. There are specific land use types associated with swampy places such as cultivation of rice, arrowroots and many green vegetables.

8.1.4 GPS Set up and Accuracy

A GPS has an expected position error (EPE) due to poor reception of satellite signals caused by several factors such as presence of thick forest or tree cover, Hills and any other obstructions. Normally one can work with a GPS with an EPE of up to 5 meters beyond which is not acceptable at this level of spatial mapping. Hence the positional accuracy of the data generated is within this error margin of $\pm$ 5 m.

When tracking using a GPS the recording time interval is set according to the size of the land use or land cover polygons though an automatic time interval is normally set at 30 seconds. It is also advisable to define the minimum size of a polygon to be mapped below which it should be merged with the nearest cover type. Considering that the working accuracy is 5 m it is then advisable not to map polygons that are less than 10 meters wide.

8.1.5 Advantages

The GPS mapping is highly detailed revealing the complex intercropping and mixed cultivations. The information can be used to train remote sensing data. The local community is introduced to the concept of resource mapping.

8.1.6 Disadvantages

Identifying the class boundaries and misclassification is one of the major errors that are encountered in ground GPS mapping. This is a problem mainly on classes such as Fallow, Fallow Grazing, Grazing, Bush, and Bush grazing. The work is quite laborious and hard considering that one has to walk in difficulty terrains. This kind of work can be applied only on very small sample areas.

The method might not be very much applicable where there are too many fences or hedges due to lack of accessibility into the farms or home compounds.

The area covered is quite small in relation to the bigger FITCA region. The results derived from such exercise might not be representative of the greater region. This implies that extrapolation of the results for the whole region must be done with a lot of care.

9 Reference Manuals

1. GERMIN GPS Manuals

2. OziExplorer Help Manual

3. ArcView Manual

4. ArcGis Manuals

5. Bouzart B, Maitima J, Nyabenge M and Reid R FITCA/EMMC 2002. EMMC Annual report 2002

10 Appendix A: Land use and cover Codes

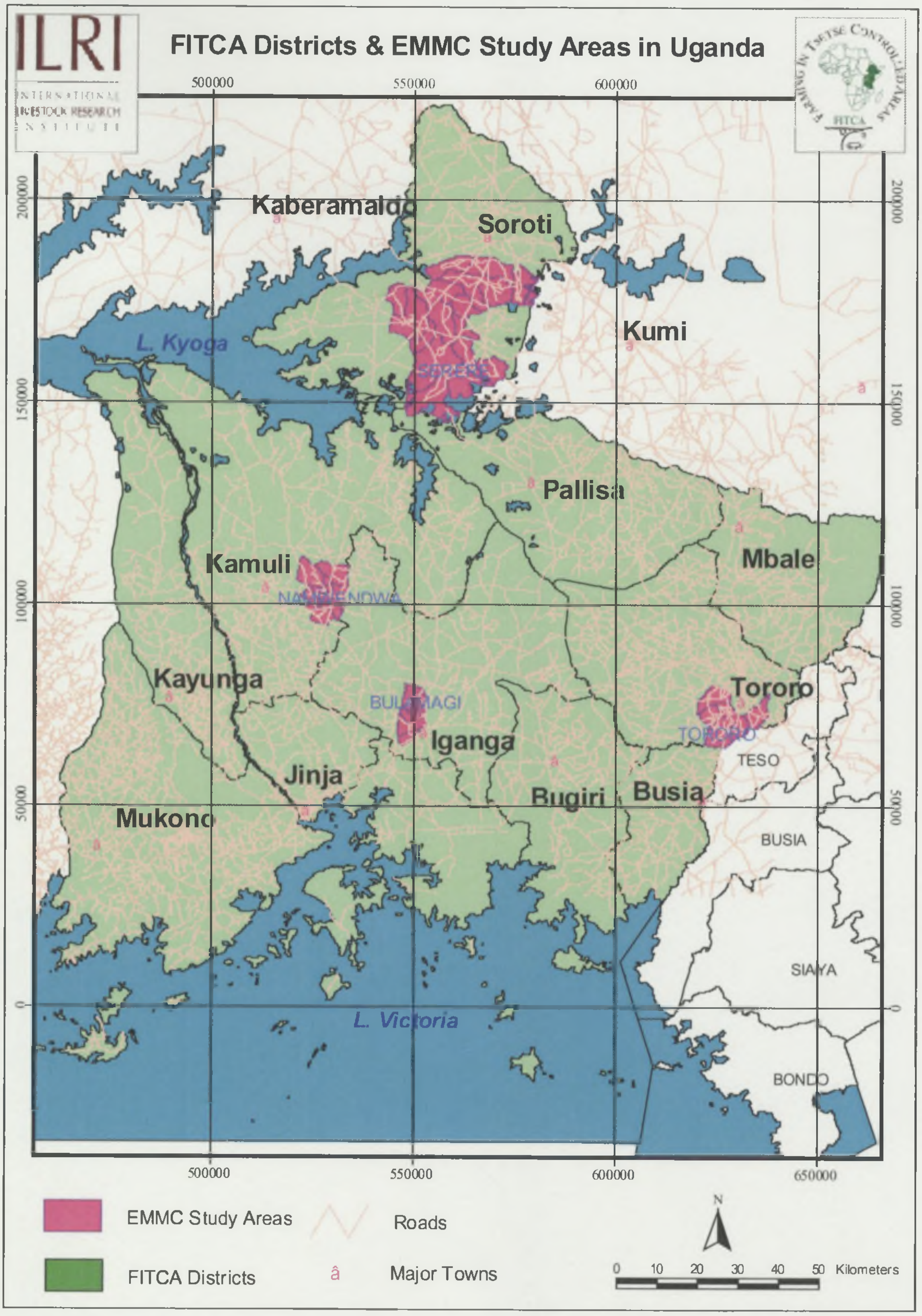
CODE	DESCRIPTION	MAIN-CLASS	RE-CLASS
AR	Arrow Roots	Crops	Annual
BE	Beans	Crops	Annual
CB	Cabbage	Crops	Annual
CO	Cotton	Crops	Annual
EP	Egg Plant	Crops	Annual
GN	Ground Nuts	Crops	Annual
MZ	Maize	Crops	Annual
ML	Millet	Crops	Annual
PN	Pineapples	Crops	Annual
PL	Ploughed	Crops	Annual
RC	Rice	Crops	Annual
SM	Sim Sim	Crops	Annual
SG	Sorgum	Crops	Annual
SB	Soya Beans	Crops	Annual
SK	Sukuma Wiki	Crops	Annual
TM	Tomato	Crops	Annual
VG	Vegetables	Crops	Annual
YM	Yam	Crops	Annual
BN	Banana	Crops	Perennial
CF	Coffee	Crops	Perennial
FT	Fruits	Crops	Perennial
CA	Cassava	Crops	Perennial-Semi
NG	Napier Grass	Crops	Perennial-Semi
PP	Pigeon Peas	Crops	Perennial-Semi
SC	Sugar Cane	Crops	Perennial-Semi
SP	Sweet Potato	Crops	Perennial-Semi
CHC	Church	BuiltUp	BuiltUp
CSH	Cow Shed	BuiltUp	BuiltUp
MIL	Flour Mill	BuiltUp	BuiltUp
SCH	School	Builtup	BuiltUp
CENT	Shops	Builtup	BuiltUp
ST	Homesteads	Homesteads	BuiltUp
BH	BoreHole	Others	BuiltUp
RD	Road	Road	BuiltUp
SWG	Sewage	Sewage	BuiltUp
BS	Bush	Bush	Natural
FL	Fallow	Fallow	Natural
FR	Forest	Forest	Natural
GR	Grazing	Grazing	Natural
SPG	Spear Grass	Grazing	Natural
TG	Tahtching grass	Grazing	Natural
SR	Shrubs	Shrubs	Natural
SW	Swamp	Swamp	Natural
WL	Woodlands/Woodlots	Woodland	Natural

11 Appendix B: Sample Data Sheet

Date:29/08/03 GPS_#: 8 Name: Sam Kagoda

Num_#	Wpoint_ID	Description of cover type	Other Comments
1	SPMZ1	Sweet Potato Maize	
2	CASP1	Cassava Sweet Potato	
3	MZ1	Maize	
4	MZBE1	Maize and Beans	
5	SPCT1	Sweet Potato Cotton	
6	MZ2	Maize	
7	SP	Sweet Potato	
.	..	...	
.	..	...	
.	..	...	
	Date:01/09/03		
1	STCF1	Homestead and coffee	
2	STCF2	Homestead and coffee	
3	MZ1	Maize	
4	STSG1	Homestead and Sorgum	
5	STBN1	Homestead and Banana	
6	MZ2	Maize	
.	..	...	
.	..	...	
.	..	...	
.	..	...	

13 Appendix D: Uganda FITCA/EMMC Study areas



12 Appendix C: Kenya FITCA/EMMC Study areas